Moderate exercise does not immediately enhance short term memory retrieval

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Three Key Words: Short-term Memory, Exercise, Resting

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Key Summary

- Investigated the impact that exercise has on short-term memory recall ability.
- In the first phase, the subjects are shown a slideshow with items they have to recall after 10 min. During this time the subject is sitting in a rest full position.
- In the second phase, the subjects are shown a new slideshow with different items and he has to recall these items after a period of moderate exercise.
- During both phases the heart rate and respiration rate is monitored.
- Our results showed that moderate exercise has no immediate effects on short-term memory recall.

Abstract

Exercise is viewed as an essential component to one's lifestyle and an enhancement for bodily functions and longevity. We investigated the impact that exercise has on short-term memory recall ability. During exercise, heart rate and respiration increase allowing increased oxygen intake and flow, mainly directed towards the brain and muscles. We analyzed how exercise impacted short-term memory by having subjects recall slides before and after exercising. Subjects viewed ten slides, rested for ten minutes, and recalled what they saw. After the resting phase, subjects viewed ten different slides, exercised in order to maintain a target heart rate for five minutes, and recalled what they saw ten minutes after seeing the slides. In order to determine the impact that exercise has on memory, the number of slides recalled during the resting and exercising phases were compared. We monitored the heart rate to assess circulation efficiency, as well as respiration rate to see if there is an increase in oxygen intake, during both phases. Our results showed that moderate exercise has no significant immediate effect on short-term memory recall, due to no significance seen in the recall during resting versus exercising phases. Our investigation concludes that moderate exercise does not have a significant effect on short-term memory recall. We found that increased sympathetic stimulation does not elicit significant increased memory function during a non-threatening situation. The effect of the sympathetic system on short-term memory recall in different situations can be examined in further investigations.

Introduction

The value of exercise is greatly underestimated by many young people today. Not only can physical fitness decrease the likelihood of contracting diseases with age, but researchers have found that it could have a positive role in learning. Recent findings show that in pre-adolescents higher levels of fitness correlate to greater hippocampus volume and increased memory function (Chaddock *et al.,* 2010). Similarly in another study, hippocampus function improved in young adult males with intense cycling exercises (Griffin *et al.,* 2011). Particularly in the elderly increased aerobic exercise correlated with increased hippocampus volume and enhanced memory (Erickson *et al.,* 2009). McMorris also demonstrated that acute exercise increases the processing speed of the working memory (McMorris *et al.,* 2011).

Memory can be encoded in three ways: visually, acoustically, and semantically. The main way for the hippocampus to store information in the short term memory is acoustic encoding, while the long

term system mainly uses semantic encoding (McLeod, 2007). Visual encoding in the short term memory is also effective. Visual encoding is the process used to store information in the sensory memory system in the form of images or icons, also called the iconic memory system (Franzoi, 2007). Also important in the discussion of memory and learning is Miller's concept of the memory span. His concept that a human adult can hold between 5 and 9 items in his/her short-term memory is described in his article *The Magical Number Seven, plus or Minus Two.* The memory span, which is the capacity of the short term memory, depends on the background and lifestyle of a person, the word length effect, which refers to easier recall of a sequence of short words over long words, and phonological similarity effect (Eysenck *et al.,* 1990). The results of Larsen *et al.,* showed that a phonologically similar list had a 25% decrease in recall (Larsen *et al.,* 2000).

The long term implications of our results involve creating new learning techniques and strategies designed especially for students at the college level. The results may motivate young adults to maintain fitness in their youth, despite the highly technological and therefore sedentary, society. Lastly, this study may implicate a correlation between exercise and an increase in attention span which may help improve current styles of teaching and studying. The elevated amount of oxygen supplied to the brain by increased respiration and heart rate will cause an improvement in the amount of information an individual can store in short-term memory.

Methods and Materials

Ethical Approval.

This project was approved by Dr. Andrew Lokuta and conforms to relevant regulations. In experiments conducted on humans informed consent in writing was obtained from each experimental subject. The study conforms to the standards set by the latest revision of the *Declaration of Helsinki*.

Biopac

The Biopac student lessons computer program, with GSR and Polygraph monitoring, was used to monitor and record the heart and respiration rates of about twenty male and female students (refer to Biopac GSR and Polygraph Manual for detailed instructions). The respiration and heart rate data was collected from the peak to peak of a respiration cycle and included the target heart rate of the subject (Figure 7). The experiment consisted of two phases, the resting phase and exercise phase, with corresponding PowerPoint presentations. The slideshows consisted of ten slides appearing at five second intervals with words and pictures. In order to test the short term memory of the subjects, the slideshows were viewed by the subject and recited to the experimenter allowing visual and acoustic encoding. During the resting phase, the subject viewed the first PowerPoint. Heart and respiration rates and the number of slides recalled total and number of slides recalled in order were recorded. The exercise phase consisted of the viewing of the second 'exercise' slideshow followed by stationary biking to increase the subject's heart rate by 60% (110-120 bpm). Once reached, this level of activity was maintained for an additional five minutes. At the end of ten minutes from the viewing of the second slideshow, the number of total slides recalled and the number recalled in order were again recorded. Two sample t-tests were conducted using a 95% confidence interval ($p<0.05$) to determine significant differences between the number of slides recalled before and after exercise.

Results

Our experimental procedure provided evidence suggesting that exercise has no immediate effect on short-term memory retrieval. Student t-tests showed no significant difference between resting and exercising recall (p=0.488) (Figures 1 and 2). Additionally, there was no correlation between resting heart rate and memory recall, as shown by our coefficient of determination value (R^2) of 0.069 (Figure 3). Likewise, there was no correlation between increased heart rate (HR) due to exercise and increased memory recall (R^2=0.126) (Figure 4). The fact that the correlation of heart rate and memory recall produced a low R^2 value means that there was considerable variation amongst our data, suggesting that there is not a relationship between exercising and memory increase. The correlation between respiration rate and memory recall before and after exercise also yielded similarly low R^2 values (resting R^2=0.125; exercising R^2=0.110) (Figures 5 and 6). For both resting and exercising memory, there were significantly more total slides recalled than the number of slides recalled in order (resting p=0.001; exercising p=0.0001). When comparing the differences between total slides recalled and number of slides recalled in order for both the resting and exercising trials, we found no significant difference (p=0.667). Because the difference between these did not change from resting to exercise, as evidence by the high p-value, it reinforces our other results that there is no correlation between exercise and increased memory recall.

Discussion

Taken together, our results show that exercise does not significantly improve short-term memory. We came to this conclusion based on results in which neither elevated respiration rate nor heart rate (indicators of exercise) correlated with memory improvement. However, when we compared the number of slides recalled before and after exercise, the difference showed that there was a one-half a slide recall increase. The fact that there was only a small increase in memory seemed to be due to exhaustion caused by the exercise. We believe that subjects were not able to rest long enough after biking but before being tested to allow the brain's short term memory to work to full potential. Another reason for the small, post-exercise memory increase may have been due to distracting nature of exercising. The distraction of exercise may have been enough for the subject's brain to dismiss the recently viewed slideshow as non-necessary information and forget it; however, when subjects were waiting during the resting trial there was nothing to distract them and possibly remove the images from their brain. If we had improved our experimental design, we may have seen greater improvements in memory recall.

In further studies, we would test the effects of exercise on memory by altering the exercise regime to include a week's worth of regimented exercise where resting heart rate was elevated by 60 percent for a test group of 15 subjects. Before exercise each day, we would have the subjects memorize a list of words. The same list of words would be used each day. On the 8th day, we would then ask the subjects to recite the memorized list. The accuracy of the answers from these subjects would then be compared to a control group. The control group would be shown the same list of words every day but would not participate in the exercise portion. By comparing these two groups, we could more accurately test whether or not exercise influenced memory. We believe this altered design would better test for an association between exercise, elevated heart rate, and memory.

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Author Contributions

Conception and design of the experiment

All members unanimously decided to use the GSR & Polygraph to record heart rate and respiration when testing the short-term memory of subjects at rest and during exercise.

Collection, analysis, and interpretation of data

All members contributed to data collection and statistical analysis (conducting and interpreting t-test p-values and R-squared values).

Drafting and Revising Article

Kristen Stowell: Results and Discussion

Sam Loveland: Results and Discussion

Cassandra Berry: Introduction and Methods

Brittany Hopkins: Graphs and Abstract

Eva Van Veen: Introduction, Methods, and Key Point Summary

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Author's Translational Perspective

The applications for this research cover a breadth of subject areas. Specifically, the negative results for an increase in memory function with aerobic exercise may translate to other situations in which aerobic exercise follows an input of sensory information. For example in learning, attempting to encode information in the working memory while engaging in immediate moderate activity is suggested to be ineffective based on the conclusions of this study. This does not discredit the possibility of moderate aerobic exercise improving long-term memory over time. This unknown information is open to future research.

Figures

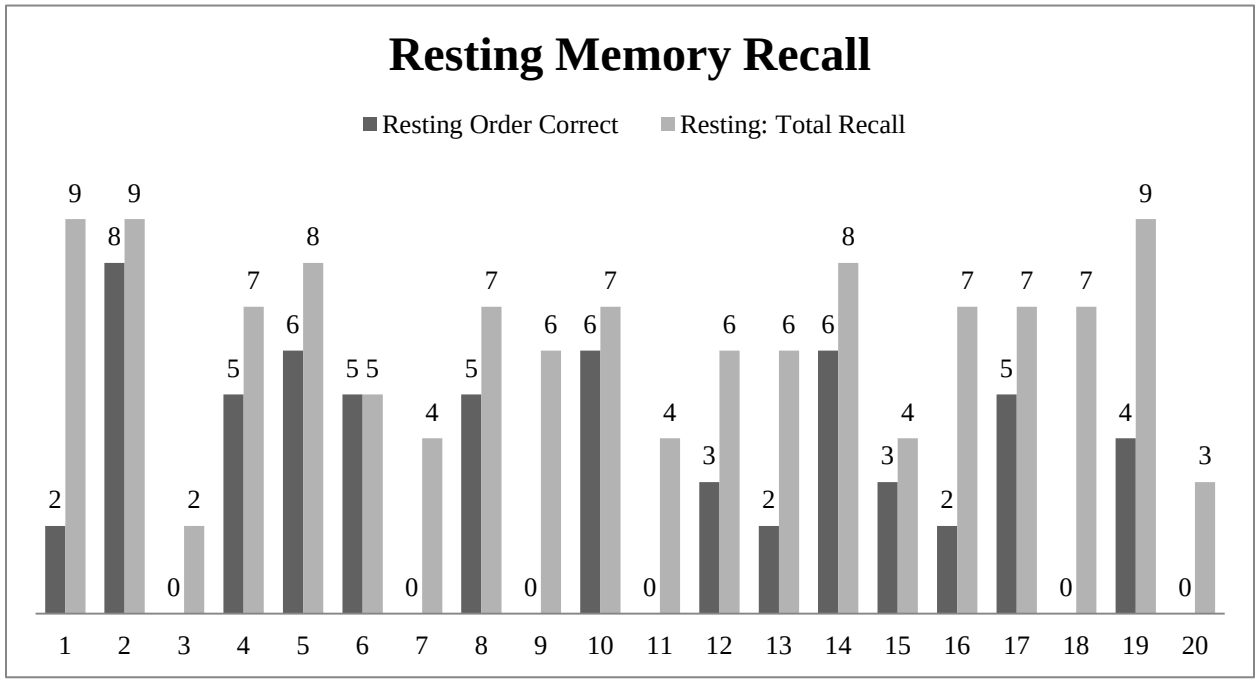

Figure 1. Figure indicates the number of items/ slides of the 'resting' slideshow presentation each subjects could recall and it indicates the number of items that could be recalled in the correct order, both after the resting period.

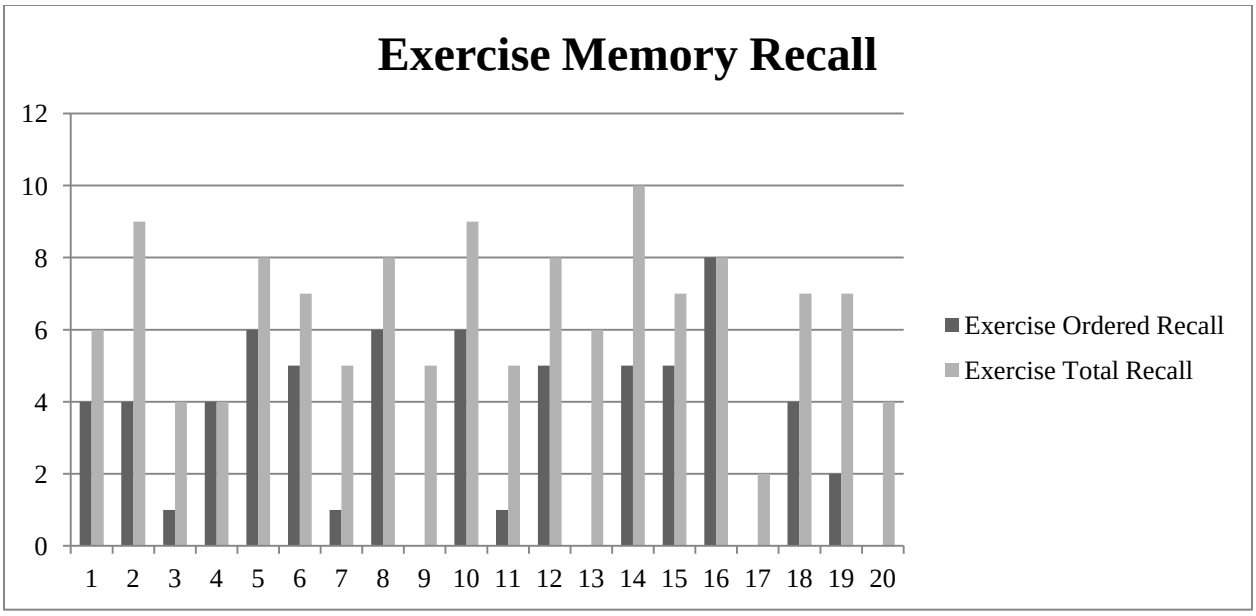

Figure 2. Figure indicates the number of items/ slides of the 'exercising' slideshow presentation each subjects could recall and it indicates the number of items that could be recalled in the correct order, both after the exercising period.

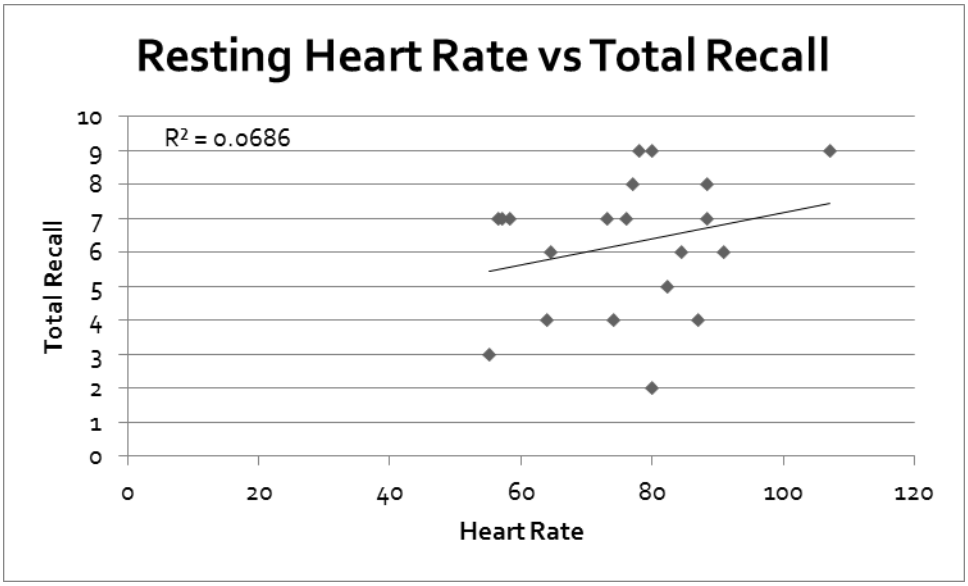

Figure 3. This graph displays the number of slides recalled as a function of the resting heart rates of each subject. The best fit line shows that a correlation does not exist between resting heart rate and amount recalled.

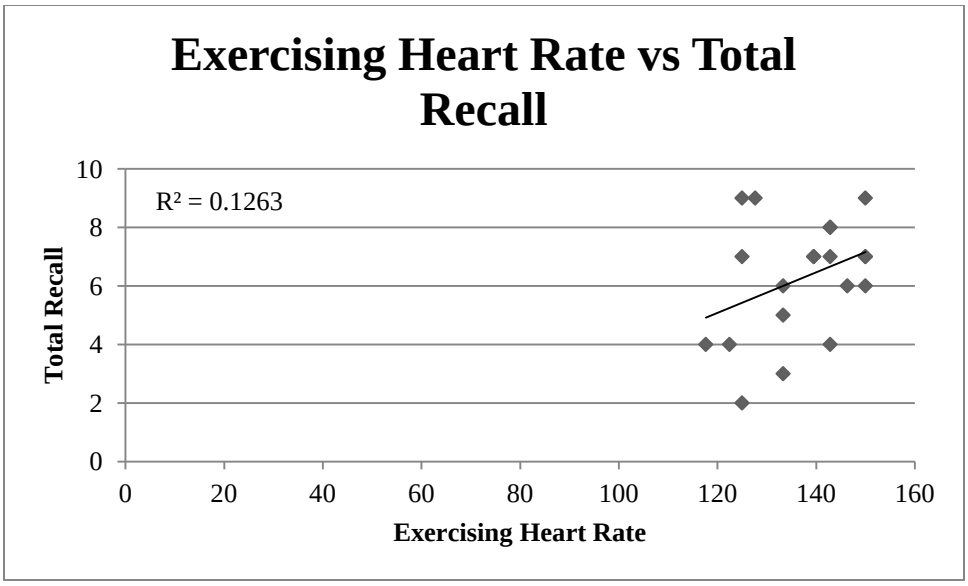

Figure 4. This graph displays the correlation between exercising heart rate and total memory recall. The R-squared value of 0.1263 shows that the two variables are not correlated. The data was inconclusive.

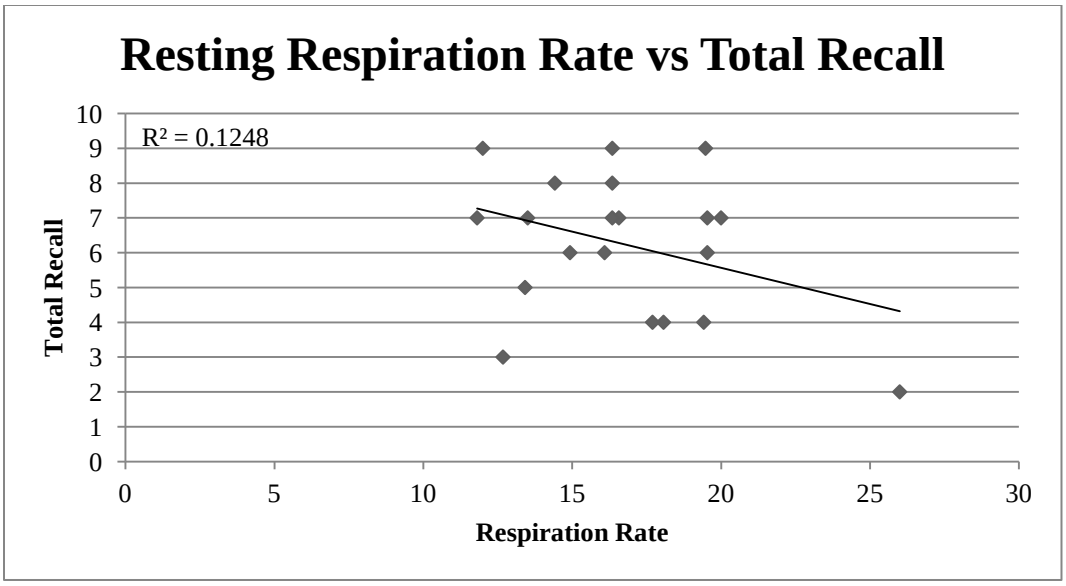

Figure 5. This graph displays the correlation between resting respiration rate and total memory recall. The R-squared value of 0.1248 shows that the two variables are not correlated; they are independent variables.

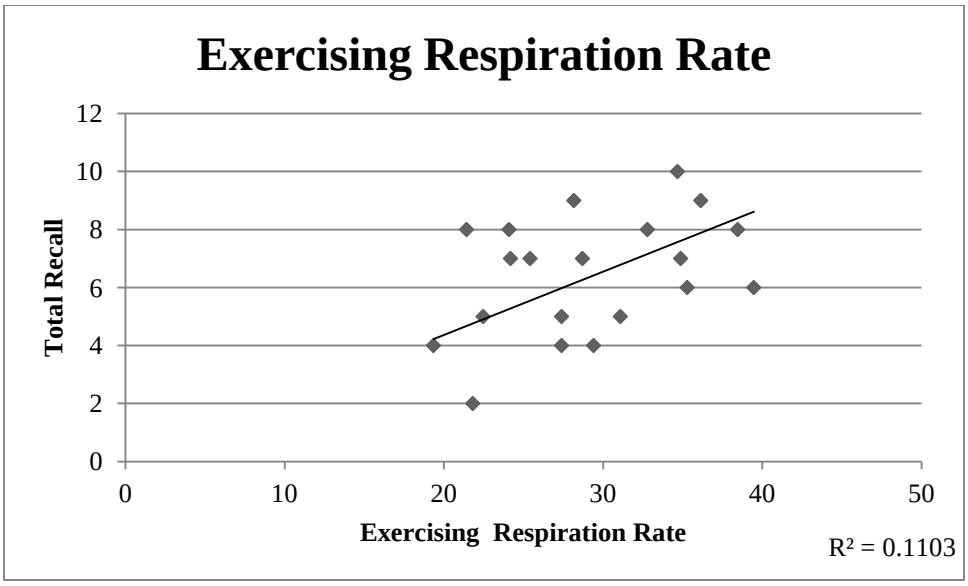

Figure 6. This graph displays the correlation between exercising respiration rate and total memory recall. The R-squared value of 0.1649 shows that the two variables are not correlated; they are independent variables.

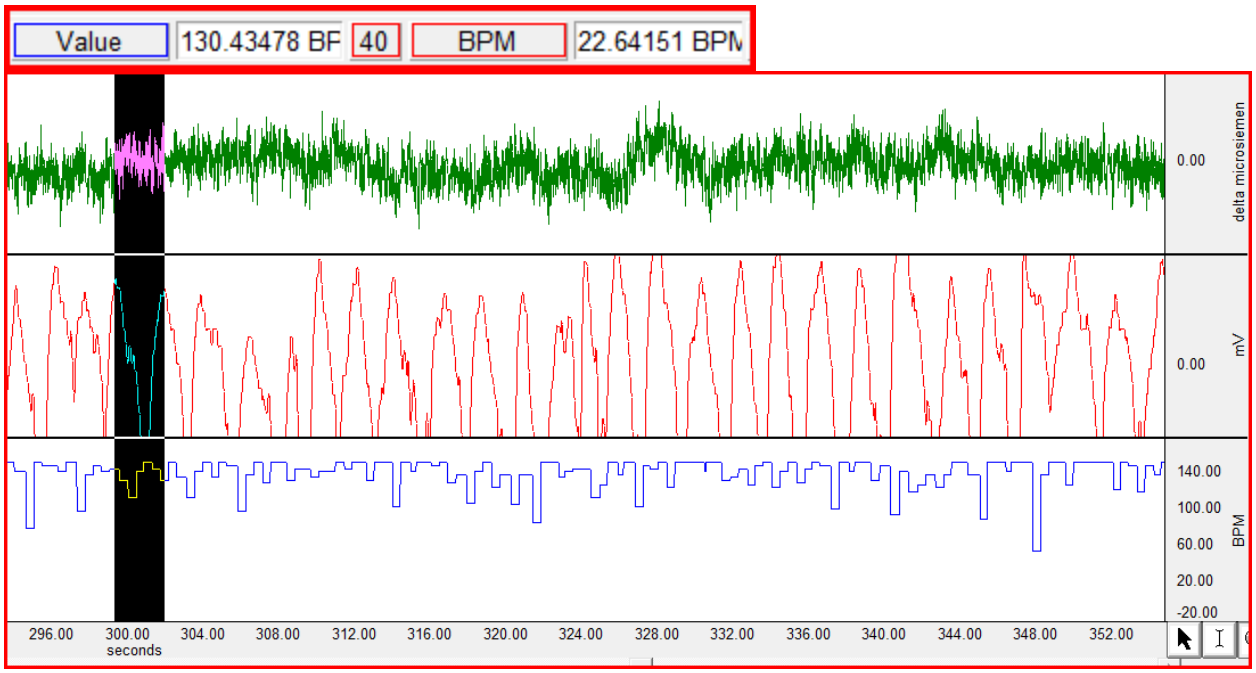

Figure 7. This is an example of data collection on the Biopac GSR & Polygraph. The highlighted section represents data collection from peak to peak respiration rate and within the target heart rate.